Spatio-temporal modelling of filter cake formation in filtration processes

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Abstract
The operation of membrane filtration units, used in many industrial, medical and environmental applications, is mainly hampered by the operational cost due to membrane fouling. Mathematical modelling can provide knowledge build-up, better process control and decision support to improve the operation of these processes. Nevertheless, the majority of fouling models is still very empirical and does not provide an adequate framework to further elucidate the underlying mechanisms of membrane fouling. Therefore, a mechanistic Euler-Lagrangian model to describe filter cake formation was developed. The Eulerian layer is based on computational fluid dynamics (CFD) and computes the Navier-Stokes equations to obtain a velocity/pressure profile of the simulated domain. The movement of dispersed particles and filter cake formation is described in the Lagrangian layer, and modelled by means of a force balance. A qualitative validation of the model, based on the Segré-Silberberg (SS) effect, revealed an important impact of wall repulsion effects and the different lift forces on the transport of particles in tubular membranes. The influence of the particle diameter, crossflow velocity and membrane flux on the migration of dispersed particles was investigated and revealed that the membrane directed migration increased with particle size and crossflow velocity. The presence of an equilibrium position of particles between the central axis and the membrane in laminar flow conditions (SS effect) and the ambiguous role of the crossflow velocity raises questions about the current turbulent operation of membrane units. The possibility to exploit this effect to reduce membrane fouling should be further investigated. Lastly, to calibrate and validate the model, an experimental filtration unit was designed by CFD in order to obtain a well-chosen flow profile. This unit enables profilometric analysis of the formed filter cake and direct observation of fouling by means of a (high speed) camera.